MICHIGAN ENVIRONMENTAL SCIENCE BOARD

INDOOR AIR INHALATION INVESTIGATION PANEL
MEETING SUMMARY
WEDNESDAY FEBRUARY 2, 2000
COURTYARD BY MARRIOTT
7799 CONFERENCE CENTER DRIVE
BRIGHTON, MICHIGAN

PANEL MEMBERS PRESENT
Dr. Lawrence Fischer, Chair
Dr. Ralph Kummler
Dr. David Long
Dr. Linda Abriola
Mr. Keith G. Harrison, Executive Director

MDEQ/OSEP SUPPORT STAFF PRESENT
Mr. Jesse Harrold, Environmental Officer

I. CALL TO ORDER

Mr. Keith Harrison called the meeting of the Michigan Environmental Science Board (MESB) Indoor Air Inhalation Investigation Panel (Panel) to order at 8:30 a.m.

II. INTRODUCTION OF PANEL MEMBERS

Mr. Harrison asked each of the Panel members to introduce themselves.

Dr. Ralph Kummler (Associate Dean for Research, Professor of Chemical Engineering, Wayne State University and a member of the MESB) indicated that he had been working on environmental problems in Michigan for 30 years.

Dr. David Long (Department of Geological Sciences, Michigan State University and a member of the MESB) stated that his specialties were water and groundwater chemistry.

Dr. Linda Abriola (Professor and Program Director of Environmental and Water Resources Engineering, University of Michigan) indicated that her expertise was in transport of organic chemical contaminants in groundwater and soils.

Mr. Harrison noted that the chair of this Panel would be Dr. Larry Fischer (Director, Institute for Environmental Toxicology, Michigan State University and chair of the MESB). His expertise is in environmental toxicology.

Mr. Harrison then introduced himself as the Executive Director of the MESB, with a background in environmental health and ecology.

III. REVIEW OF GOVERNOR'S CHARGE

Mr. Harrison indicated that the Michigan Department of Environmental Quality (MDEQ) has been working on the development of generic cleanup criteria to implement the provisions of Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Part 201). In 1995, amendments to Part 201 were enacted that require the MDEQ to use reasonable and relevant exposure pathways in developing generic, land use based cleanup criteria. The MDEQ has identified inhalation of volatile hazardous substances that migrate into indoor air from contaminated soil and groundwater as a reasonable and relevant exposure pathway. Since early 1997, the MDEQ has been working on development of generic cleanup criteria for indoor air contaminants attributable to migration from environmental contamination. The MDEQ has proposed administrative rules that describe conditions under which the indoor inhalation pathway is deemed relevant and has set forth algorithms for calculation of generic criteria.

On October 29, 1999, Governor John Engler requested the MESB to determine whether the proposed MDEQ approach provides a scientifically and technically defensible strategy for development of generic cleanup criteria for the indoor air inhalation exposure pathway. Specifically, the MESB was requested to evaluate the MDEQ's approach to evaluating these risks, as described in the document entitled*, Part 201 Generic Groundwater and Soil Volatilization to Indoor Air Inhalation Criteria, Technical Support Document* (TSD).

IV. PRESENTATION BY MR. ANDREW HOGARTH

Mr. Andrew Hogarth (Assistant Division Chief, Environmental Response Division, MDEQ) began by stating that the cleanup criteria under consideration were developed for both soil and groundwater. These criteria are related to the potential for soil and groundwater contaminants to migrate through the soil into indoor air spaces. Mr. Hogarth noted that the statutory authority for the criteria comes from Part 201, which among other things establishes liability standards, provides for generic cleanup criteria to be developed by the MDEQ, the development of a list of contaminated sites, and funding mechanisms.

Section 20a of Part 201 requires the MDEQ to develop risk-based generic cleanup criteria based on land use categories. Therefore, generic criteria are based on exposure assumptions for typical human behaviors that are consistent with a particular land use. Section 20a also provides for three types of remedial actions: generic, limited, and site-specific:

- Generic remedial action is based on generic cleanup criteria where residual contaminants left after the cleanup are below the generic criteria that are applicable to the particular land use category. Generic criteria are very important for effective implementation of the Part 201 program. They allow people to know in advance what will be approved, which speeds decision-making and reduces transaction costs.

- A limited remedial action allows for contamination at concentrations above the generic criteria to be left in place, provided that appropriate land use restrictions are filed with the deed to assure that the integrity of the remedy is maintained. Limited remedies often involve a waste containment structure or an exposure barrier preventing contact with contaminated soil exceeding generic criteria.

- Site-specific remedial actions use alternative criteria based upon alternative exposure assumptions. Similar to limited remedies, a site-specific remedy requires a land use restriction to assure that future property use is consistent with the site-specific assumptions.

Land use categories include residential, commercial, industrial, recreational and other, with the commercial category divided into four subcategories. The MDEQ has developed generic cleanup criteria for residential, commercial and industrial land uses. The residential criteria are the most protective, and assume that the land is clean enough for any use. Potential future uses are considered in approving remedial action plans.

Generic cleanup criteria take into account the toxicity of the chemicals involved, the established acceptable risk level (which for carcinogens is one in 100,000), and the kinds of exposures that may occur on the property. For a generic nonresidential remedy, a land use restriction filed with the deed is required to assure that future land use is consistent with the assigned category.

For soil, some generic criteria are based on the impact the soil will have on other media, such as leaching of contaminants into groundwater or migration of contaminants into the air. These criteria are based upon reasonably conservative approximations for soil properties that are expected in Michigan. Facility-specific generic criteria are possible for persons that can demonstrate that the soil characteristics on their property are different from those the generic criteria are based upon, and that these soil characteristics are not likely to change.

With a limited category remedial action, future land use restrictions are more extensive than with a generic cleanup. Nonresidential generic remedies only require that future property uses be controlled consistent with the chosen land use category. However, for a limited remedy that depends, for example, on an exposure barrier, restrictions filed with the deed would be necessary to ensure that the barriers are maintained and not compromised. Another example of a potential limited category remedial action is a situation where soil contamination does not pose a threat to indoor air in an existing structure due to the large size of the structure, much larger than the generic assumption about building size. In this situation, a limited remedy could be put in place that includes a restrictive covenant filed with the deed that would prohibit future construction of smaller buildings on site.

Site-specific criteria can be substituted for generic criteria based upon generic exposure assumptions, when it is possible to use alternative human exposure assumptions that are more appropriate for the site. One example is direct contact criteria for soil. While generic soil direct contact criteria are based on an exposure frequency of 112 days per year for 21 years, a fenced warehouse might only be visited once a month. Site-specific criteria based upon actual reasonable exposure frequency could be calculated in such a situation. A restrictive covenant filed with the deed for the property would be required to assure that exposure associated with future property use remains consistent with the site-specific assumptions.

The MDEQ Cleanup Criteria Training Manual (Manual) provides a structure for evaluating remedial action plans and making decisions about cleanup criteria. It includes a list of conditions to evaluate in assessing compliance with Part 201 criteria. The Manual delineates the exposure pathways and other factors that need to be considered at a site of contamination, linking them to reference guide sheets and generic criteria that have been developed. Cleanup criteria have been listed for 278 chemicals and grouped in tables according to pathways and land use categories. Bold squares around certain criteria identify them as being the most conservative. The guide sheets in this document discuss the purpose of the criteria and briefly touch on important issues of applicability. For example, the Generic Groundwater Volatilization to Indoor Air Criteria (GVIIC), are based upon groundwater at three meters below the ground surface. If the groundwater is actually less than three meters below ground surface, then the generic criteria are not applicable. Also, where calculated criteria exceed their solubility in groundwater or saturation levels in soil, the generic criteria default to the solubility or saturation levels.

There are generally three ways generic criteria are used. The first relates to remedial actions where a known contaminated site is cleaned up in accordance with the statute. Generic criteria are one framework for deciding how clean is clean. A second use of generic criteria involves the issue of due care. Part 201 does not require non-liable parties to clean up their property. However, they must satisfy due care obligations to assure that unacceptable exposures do not occur. These property owners can use the generic criteria to determine if contaminant concentrations on their site will likely lead to unacceptable exposures, and whether they need to implement a response action to clean up the contaminant or prevent exposure. Once the site meets generic residential criteria, it is no longer a facility regulated by statute, and there is no further obligation to monitor or exercise due care because it is no longer a contaminated site. A third use of generic criteria is facility determination. The generic criteria are used as a threshold to determine whether a site is contaminated to the point where it falls under the regulatory scheme of Part 201. Property at which there is contamination that exceeds the generic residential cleanup criteria is considered to be a facility, as that term is defined in Part 201, and is subject to the provisions of Part 201.

V. PRESENTATION BY MR. JEFFREY CRUM

Mr. Jeffrey Crum (Environmental Response Division, MDEQ) provided a broad overview of the quantitative approach (the vapor migration model) used to develop Part 201 generic indoor air criteria for soil and groundwater, and to discuss the health risk assessment aspects of the generic criteria development process and the application of the generic criteria in the Part 201 cleanup program. Risk assessment requires three basic types of information, exposure or estimates of intake, chemical toxicity or how hazardous the chemical is, and the chemical concentrations in the medium of interest, groundwater and soil in this case.

Risk assessments are designed to yield estimates of risk as a function of exposure, toxicity and concentration. In developing a generic criterion, the acceptable target risk level and information on the chemical toxicity have already been established. So the focus is on characterizing how much human exposure may occur. This exposure potential (e.g., frequency and duration) is based in part on the land use category. Certain Part 201 generic criteria must also consider the chemical interactions within the media in which it resides to estimate migration to another medium where human exposure is expected. This allows for the development of a concentration (i.e., a generic criterion) in one medium that is protective of the medium where exposure will occur.

Before the development of Part 201 generic indoor air criteria, the standards used were the Tier 1 Risk-Based Screening Levels (RBSLs) from the American Society for Testing and Materials (ASTM) Risk-Based Corrective Action (RBCA). This application was another streamlined approach for contaminated site assessment and response. In 1997, a technical subcommittee of the Part 201 advisory group was formed to develop the Part 201 generic indoor air criteria. This group was made up of participants recommended by members of the Part 201 advisory group, and technical staff of the MDEQ. The approach that was decided upon was that described by Johnson and Ettinger in their 1991 scientific paper in *Environmental Science and Technology*. Technical subcommittee efforts were focused on developing generic input values for parameters within the model that were most sensitive. However, the cleanup program allows the use of site-specific parameter values in place of the generic input values provided they are demonstrated to be appropriate and representative of the site conditions.

The first generic criteria were published January 1998. Some of the basic objectives were to develop a simple approach that would be applicable statewide at a variety of sites. This approach should represent basic physical and chemical processes associated with the indoor air pathway, and should be easily modified for better representation of specific site characteristics. The process used for development of generic input values is based on U.S. Environmental Protection Agency (USEPA) Risk Assessment Guidance for Superfund (RAGS). Estimates of reasonable maximum exposures (RME) are determined by identifying the most sensitive parameters within the calculations and setting those at upper percentile values. These values would then be combined with average or central tendency estimates for the other less sensitive parameters.

The Johnson-Ettinger model was chosen for development of Part 201 generic indoor air criteria because it incorporates both diffusive and convective transport mechanisms. Including the convective transport processes accounts for the effect that structures (buildings) and surrounding soil can have on vapor migration. The Johnson-Ettinger model not only agrees with a more sophisticated three-dimensional numerical model, but also has undergone a peer review process and is used across the country for risk-based corrective actions at contaminated sites. The Johnson-Ettinger model is a one-dimensional analytical solution for diffusive and convective transport that estimates an attenuation coefficient. The attenuation coefficient is the ratio of the vapor concentration in the building to the vapor concentration at the source. The first assumption of this model is that contaminant levels are not reduced over time (i.e., infinite source), and contamination is evenly distributed in the groundwater and soil. The contamination is considered to lie within the downward, vertical plane of the building. In the model there is no resistance to contaminant flow from one phase to another (i.e., boundary layer resistance is zero). Steady state equilibrium partitioning is also assumed such that all contaminant phases are in proportion to each other and the total concentration. Soil is assumed to be homogenous for purposes of diffusive and convective transport. Other assumptions include that contaminants are not biodegraded or biotransformed. Vapors are assumed to enter through cracks or openings in the subgrade portion of the structure. All vapors enter the basement; there is no leakage of contaminant vapors around or away from the building. In the building, ventilation and pressure are assumed to be constant over time and contaminant dispersion within the building is instantaneous and evenly distributed.

Model inputs can be divided into separate categories. The chemical properties include the Henry's Law Constant, the soil-water partition coefficient, and molecular diffusivity coefficients for air and water. Another category includes the subsurface physical characteristics for groundwater and soil. Especially pertinent to groundwater characteristics is the capillary fringe, the area above the water table. Soil type considers factors such as soil porosity and vapor permeability. The last category involves the characteristics of the building.

In a conceptual diagram for soil contamination, contaminants can be seen to volatilize from the soil into the adjacent soil-air pore space. Diffusion acts to move the contaminant up to an area referred to as the building zone of influence. Here convective vapor transport occurs as the result of a pressure differential existing between the building envelope and the underlying soil such that vapors are swept into the building. Next the building ventilation results in the residual building concentration that provides the attenuation coefficient, again the fraction of the soil vapor concentration in the building relative to the soil vapor concentration that was at the source. For groundwater, there is a source-building separation distance of one meter and a step in the modeling accounts for the reduction of vapor passage through the capillary fringe. The initial assumption is that the capillary zone above the groundwater is free of contamination. One factor affecting the convective transport of contaminants is the pressure in the building which, although it can be positive, is assumed to be slightly negative as an annual average estimate.

There are several generic input assumptions needed for the model. Included are assumptions associated with building size and ventilation, equilibrium partitioning, source-building separation distance, and specifics for different land use categories. There are also assumptions related to the soil vapor convection modeling component, such as the pressure differential, and parameters related to soil type. For groundwater, assumptions will be the same as for the soil plus the characteristics of the capillary fringe and its thickness. A sensitivity analysis was conducted for each variable by the USEPA. The justification for each generic input parameter value can be found in the MDEQ TSD.

The first variable is building size. Data from the Internet and elsewhere were obtained on homes built in the Midwest from 1975 to 1995. An upper percentile value of 1,200 square feet was chosen for the generic residential building size. Additionally, 90 percent of the homes had some type of below grade structure. So the final assumption is a two-story ranch type structure with eight-foot ceilings and a basement. For commercial and industrial structures, there can be a wide range of building sizes and consideration was given to separate office-type spaces that may exist within, or adjacent to larger buildings. A 1992 report on the types of commercial buildings constructed yielded an upper percentile value of 4,000 square feet. This is based on buildings categorized as mercantile and service. The building size is a moderately sensitive input compared to other parameters. Information on the relative sensitivity of parameters can be found in the USEPA document entitled *Users Guide for the Johnson-Ettinger Model.* Because the MDEQ model required generic assumptions for a great number of inputs, efforts were focused on those inputs with the greatest sensitivity.

Building ventilation relates air volume to the air exchange rate, which is the number of times per hour that a volume of outdoor air equal to the volume of indoor air enters the building. This is expressed in units of volume changes per hour, and is the function of natural and mechanical means of ventilation, as well as the tightness of the structure. Because air exchange rates vary through the year an annualized value is estimated for use as a generic input value. One air exchange per hour is used as the default input for the air exchange rate for residential and two air exchanges per hour for commercial/industrial, the latter accounting for the higher traffic flow common to these buildings. The sensitivity for this variable is considered medium by the USEPA. The sensitivity analysis includes the variability of the parameter, which in this case has a fairly narrow range. Determination of the actual exposure to airborne contaminants requires information regarding the actual concentration of chemicals in the air, as well as the frequency and duration of human exposure.

Since a basement was assumed for residential structures there was a need to establish a separation distance between the basement foundation and the groundwater considering seasonal water fluctuation. This input parameter is referred to as the source-building separation distance. The generic input value assumes a three-meter depth below ground surface to the water table, which allows a one-meter separation distance from the foundation. This degree of separation between the groundwater table and the foundation was thought to protect against seasonal groundwater table fluctuations. If the actual groundwater is found to be shallower the generic criteria are not applicable, and if the groundwater is appreciably deeper, alternative facility-specific generic criteria can be calculated. For commercial/industrial buildings without a basement, (typical for service and mercantile type establishments) there is a greater diffusion path length for vapors to travel. The source-building separation distance for the soil contamination scenario is simply related to the foundation/slab thickness, which is assumed as 15 centimeters.

Equilibrium partitioning of vapor addresses the first step of contaminant movement. For contaminants in groundwater Henry's Law Constant is applied which states that contaminant concentrations in the aqueous phase are in equilibrium with their vapor phase. A temperature adjustment factor is added to the Henry's Law Constant to account for decreased volatility at lower subsurface soil temperatures. Some information supporting this adjustment is available in the USEPA's Chem8 Database. Reduction of the amount that goes into the vapor phase has an equally proportionate effect on the calculated criteria. For soil, concentrations are based on dry weight and equilibrium partitioning is a function of the soil-water partition coefficient, the subsurface conditions, and organic composition.

Vapor permeability is a function of soil particle size and shape and is defined as the resistance to airflow in a porous medium. The generic indoor air criteria are based on one soil type, loam. Although there is more sand in the northern and western areas of Michigan and more clay in the eastern region, a balance of these soil types was chosen for calculating the generic criteria. The characteristics of the loam soil type affect diffusive transport in the vadose zone. For convective vapor transport processes a sandy loam soil type was chosen, because building structures are typically designed to be back-filled with sandier soil for better drainage.

One important and particularly challenging input parameter is the indoor-outdoor pressure differential. This variable is a function of meteorological conditions, such as ambient temperature changes and wind loading on the structure which can create periodically negative pressures within a building. Negative pressure can occur as the result of "stack effect" from heating the interior of the building, and mechanical ventilation can also cause negative pressures. Indoor atmospheres have been documented as ranging from zero to two Pascals throughout the year, and the Johnson and Ettinger article suggests a long-term average value of one Pascal. Continuous positive pressure, an example of engineering control, could impede vapor infiltration.

One chemical considered for comparison was benzene. At five parts per billion, benzene in groundwater would meet the Part 201 generic indoor air criteria, although the drinking water pathway would still be an issue. A deed restriction to limit water use or a cleanup could be applied to address the drinking water pathway.

One factor that has a large impact on the calculated part 201 generic indoor air criteria is soil type. While the ASTM chose a dry sand, the USEPA chose a loam soil type with a high water content, approaching 70 percent, to represent soil moisture conditions for subsurface soil. Chemical transport through water will be limited. Generic input assumptions for the soil type in Michigan need to balance the clay and sand diversity across the state. Another parameter is the ratio of the crack area to the total building area below grade. The MDEQ assumed a two order of magnitude smaller value for this parameter than ASTM in the calculation of the RBCA Tier 1 RBSLs. The Johnson and Ettinger paper assumed a one-centimeter wide crack every 100 centimeters. The size and frequency of actual openings depends on the construction type and quality. Using soil or stone for floors or walls allows greater openings.

In certain applications of the indoor air criteria professional judgement is used. For example, small areas of groundwater with quantities of contamination are unable to provide adequate source strength to produce vapor emissions into a building over the time period (e.g., 30 years for residential or 21 years for commercial/industrial land uses) assumed in the calculations.

VI. PANEL DISCUSSION

Dr. Abriola asked whether there was a sampling protocol to see if sites actually met the generic criteria. Mr. Hogarth answered that adequately demonstrating whether a site met this criteria, which used a lot of statistics, was a separate issue. There is always characterization of the site with sampling of soil and water contaminants.

Dr. Long asked if the generic criteria could be considered a framework whereby owners of a site could take their measurements and put them into already established protocol. Mr. Hogarth stated that use of the generic criteria would eliminate the need to do their own modeling and independently come up with a process for developing criteria. The tables, which are available on the Internet as well as in the guide sheets, have criteria for acceptable limits for specific chemicals.

Dr. Fischer asked how the criteria could be used for indoor air. For example could the model be used to suggest that if soil and groundwater benzene levels are low, the chemical in the air must be coming from carpet or elsewhere. Mr. Hogarth replied that the cleanup criteria are designed for the property and do not focus on what happens to be in the building. They deal rather with how the property is going to be cleaned up and if it will be safe to build on in the future. Mr. Hogarth added that indoor air monitoring might be an option for people, without dealing with generic criteria, to demonstrate compliance. Mr. Crum added that the model is not used for indoor air monitoring, but is used to estimate vapor migration from groundwater or soil. An acceptable indoor air concentration is a combination of the exposure assumptions and toxicity assumptions.

Dr. Kummler questioned whether the models used by the MDEQ to develop their criteria had been validated through field data or other methods. He expressed concern about the assumption that there would be flow into the building structure. He stated that it would seem plausible to design a structure that diverts those vapors around the structure, that sealed floors could keep out the vapors. Mr. Hogarth replied that this was certainly an option. In this case, generic criteria would not need to be met, but land use restrictions might be needed to ensure continuity.

Mr. Harrison inquired about the technical backgrounds of the stakeholder subcommittee. Mr. Crum responded that these were 15 to 20 experts selected by the stakeholders to represent their interests and included geologists and engineers as well as toxicologists and industrial hygienists.

Dr. Kummler asked what percent of cleanup decisions were likely to be based on generic criteria and what percent would be site-specific. Mr. Hogarth replied that during the past three years over 108 remedial action plans had been submitted for approval. Two of those were denied and five needed more information for a decision. The generic criteria were able to facilitate virtually all of the 100 plus cases approved.

VII. PUBLIC COMMENT

Mr. John Barkoch (Dragan Corporation) noted that while basements can create positive pressure for buildings, industry typically relies on ventilation to remove chemicals from the air; actually creating a negative pressure.

Ms. Beth Rikkan (MichCon) questioned whether there had been a consensus in the MDEQ stakeholders' group involved in development of the generic criteria. Ms. Meg Gavakati (MichCon) added that she had been involved in the subcommittee meeting and noted that the main conflict in the group had been opposition to using the Johnson-Ettinger model. She stated that use of this model had not been agreed upon by the group. Mr. Crum replied that although there were parameters upon which the group did not reach consensus, on the majority of parameters they did. Some information on building size and soil vapor permeability was provided by outside parties. Although there was opposition to use of the Johnson Ettinger model, an alternative approach was not provided and time constraints necessitated using the framework available.

VIII. PANEL ASSIGNMENTS

Dr. Fischer suggested that the Panel discuss the writing assignments. He asked whether the Panel members had enough information from the presenters to start formulating some ideas. Dr. Kummler agreed that the speakers had presented a good overview and had provided some useful material. He questioned whether there was information on any difficulties the regulated community has had with these issues. Ms. Chris Flaga (MDEQ) noted that representatives of the regulated community were present at today's meeting and after discussion with their colleagues would be able to present any additional relevant data.

Dr. Fischer reiterated that he was interested in the scientific justification for the model chosen and would appreciate hearing any concerns, and the data for those concerns, from the regulated community. Dr. Kummler added that he was uncomfortable with the sensitivity analysis and uncertainty, and could not judge if the model was realistic. Dr. Abriola characterized the science behind the model as fairly sound, but was concerned about the use of particular parameters and how sensitivity was factored in. Dr. Fischer noted that the inputs could reflect a management decision, rather than being strictly scientific. He questioned the degree of the conservative approach chosen, and how closely the model is able to predict indoor air concentration. Mr. Crum replied that he had received a draft of a manuscript submitted for publication in the *Journal of Soil Contamination* that addressed validation of the Johnson-Ettinger and other models. He stated that he would attempt to provide this information to the Panel.

IX. ADJOURNMENT

The meeting was adjourned at 12:03 p.m.
Keith G. Harrison, M.A., R.S., Cert. Ecol.
Executive Director
Michigan Environmental Science Board